Growing quality grapes in a warming climate

Victor Sadras, Martin Moran, Marcos Bonada, Paul Petrie

7th Australian Wine Industry Environment Conference, 25 Sep 2014

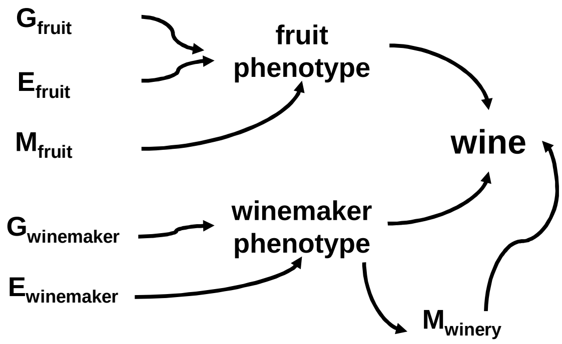
Wine is G x E x M, twice

The phenotype includes all traits of an organism other than its genome

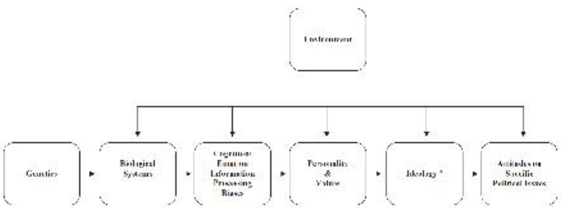
Phenotypic traits	
hormones	winemaker's sense of smell
metabolic pathways	remembered phone numbers
Malbec skin anthocyanin	nervous tics
Shiraz seed tannin	baby's smile
vine yield	toothache

West-Eberhard 2003 Developmental plasticity and evolution (Oxford University Press)

Wine is G x E x M, twice



GxE model of political ideology



Smith et al (2011) Political Psychology 32:369-397

Ambient temperature is important part of E_{fruit}

Historical interest
- warm v cool regions
- varietal adaptation

Climate change
- long-term trends (~0.01 °C per year)
- heath waves (timing, intensity, duration)

We know less than we think about temperature

Methods to assess temperature effects on vines and wines

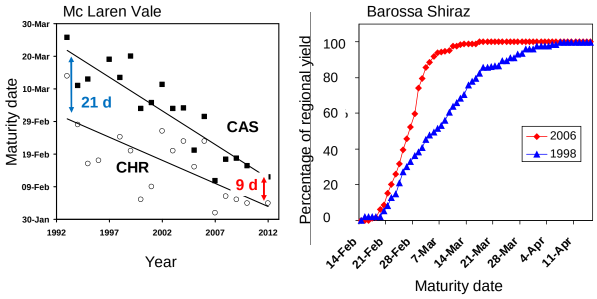
Indirect

comparisons in time
comparisons in space
modelling

Direct

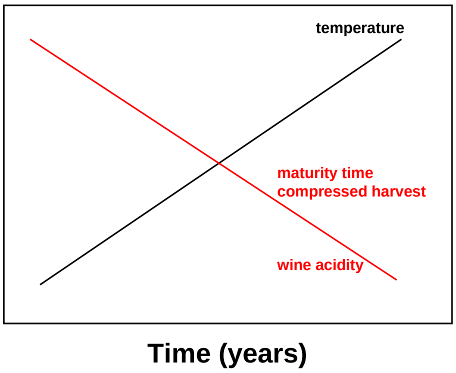
controlled environments
field

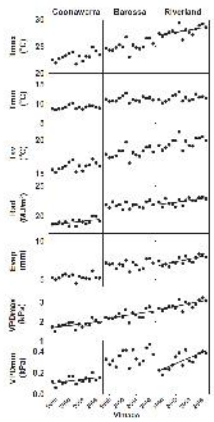
Bonada and Sadras 2014 Australian J Grape & Wine Research *in press*



Paul Petrie unpublished

indirect approach is bound to be inconclusive





indirect approach
regional or seasonal comparisons

Sadras and Petrie 2011 Australian J Grape & Wine Research 17, 199-205

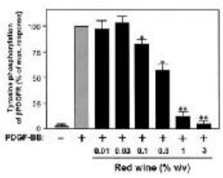
Indirect method (e.g. epidemiological study)

Low mortality from coronary hearth disease despite high intake of saturated fat in France.

This paradox may be attributable in part to high wine consumption.

Renaud & de Lorgeril 1992 Wine, alcohol, platelets, and the French paradox for coronary heart disease. *The Lancet 339, 1523-1526. (Cited by 2452)*

Direct method



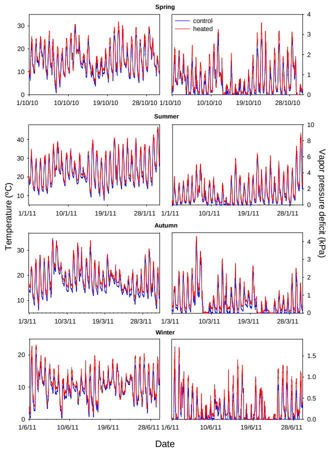
Rosenkranz et al 2002. Inhibition of the PDGF receptor by red wine flavonoids provides a molecular explanation for the “French paradox”. *The FASEB Journal 16, 1958-1960.*

Large scale open-top heating systems

(9 vines per rep x 3 reps + buffers)

Passive, daytime +2 to 4 °C

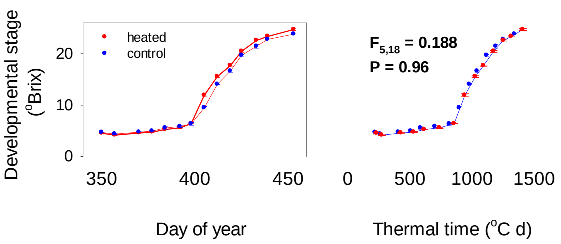
Active/Passive, day & night +2 °C

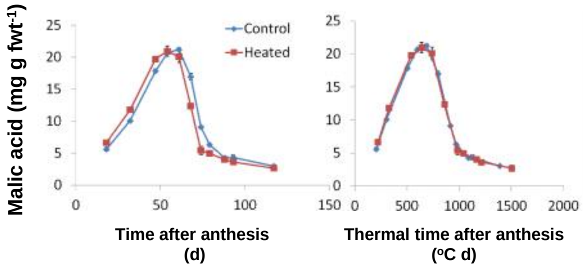


Design Criteria

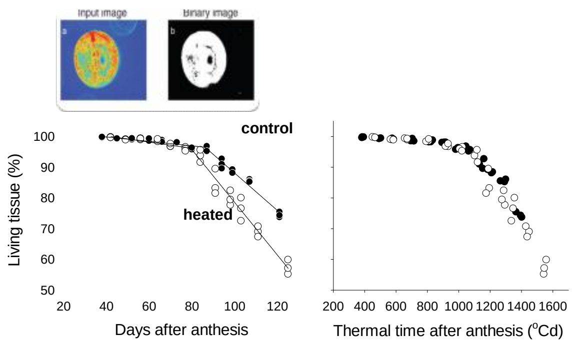
1. **Minimises biologically important secondary effects.**
2. **Reproduces the daily and seasonal cycles of temperature and vapour pressure deficit.**
3. **Does not increase relative humidity, hence allowing for increased vapour pressure deficit.**
4. **Has structural strength to withstand the weather (particularly wind) to ensure a reasonable longevity.**
5. **Allows for number and size of replicates required for statistical resolution and viticultural needs, including sufficient fruit for meaningful wine production.**

Differences in phenology were largely undetectable on thermal time indicating a true thermal effect rather than experimental artefact





Sweetman et al 2014 J Exp Bot



Bonada et al. 2013 Australian J Grape & Wine Research 19:87-94

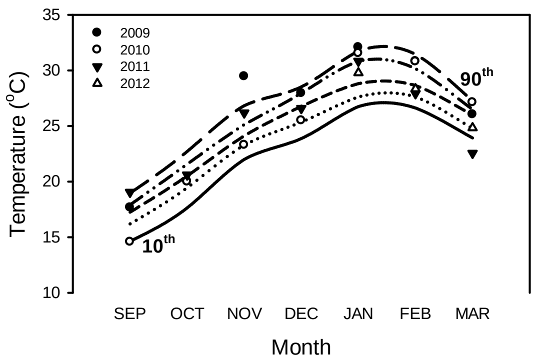
Factorial experiments

Exp 1
2 temperatures (high, control) x 4 varieties x 3 years

Exp 2 (Shiraz)
2 temperatures x 2 fruit loads (thinned, control) x 2 years

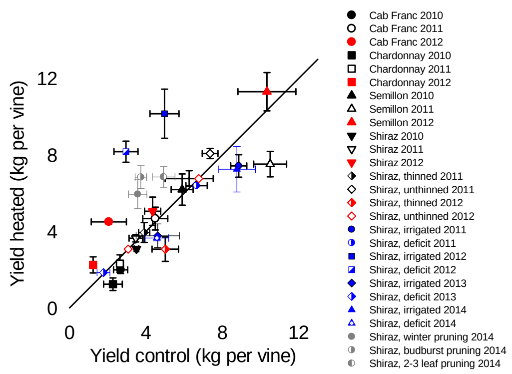
Exp 3 (Shiraz)
2 temperatures x 2 water (irrigated, deficit) x 2 years

experiments explored a good range of Barossa seasonal variation



asymmetric effect of warming on yield

46% reduction to 177% increase, but mostly neutral



Sadras & Moran (2013) Agricultural and Forest Meteorology 173:116-126

elevated temperature reduced Botrytis incidence and increased quality yield

Temperature	Water supply	Total Yield (kg vine^{-1})	Botrytis incidence	"Healty" Yield (kg vine^{-1})
control heated	irrigated	8.9 ± 0.42 7.4 ± 0.59	0.34 ± 0.076 0.05 ± 0.052	5.8 ± 0.37 7.0 ± 0.42
control heated	water deficit	6.7 ± 0.56 6.4 ± 0.01	0.24 ± 0.029 0.03 ± 0.018	5.0 ± 0.23 6.2 ± 0.10
P-temperature		0.15	0.003	0.01
P-water supply		0.02	0.336	0.05
P-interaction		0.29	0.514	0.99

Shiraz, Experiment 3

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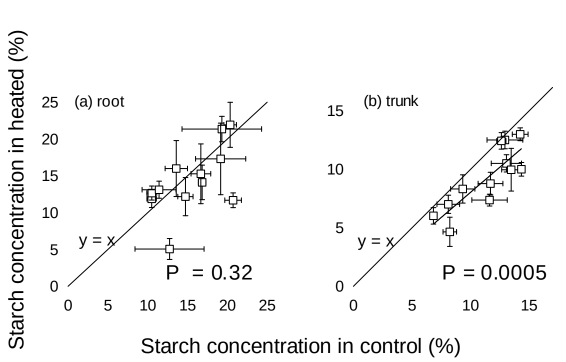
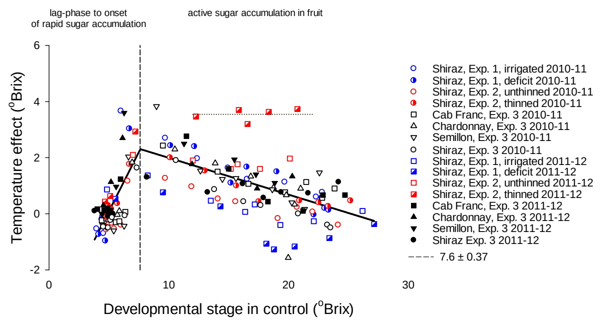
elevated temperature reduced starch concentration in trunk



Sadras & Moran (2013) Agricultural and Forest Meteorology 173:116-126

nonlinear thermal effect on grapevine phenology



Sadras & Moran 2013 Agricultural and Forest Meteorology 173: 107-115

time-series over-estimate actual thermal effect on maturity

Maturity = 21.6 °Brix

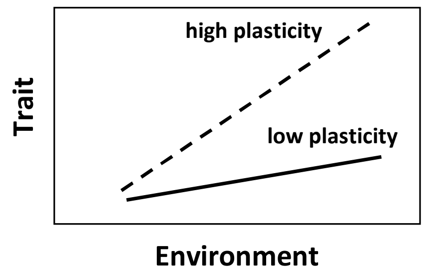
Season	Exp.	Actual shift (d) mean	Actual shift (d) range	Expected shift (d) lower	Expected shift (d) upper
2010-11	1	1.5	0.3 to 2.6	9.6 ± 1.37	14.3 ± 0.4
	2	1.2	0 to 2.3	4.3 ± 1.61	6.4 ± 2.32
	3	3.0	-0.6 to 4.3	6.7 ± 1.40	9.9 ± 1.82
2011-12	1	-1.4	-2.3 to -0.6	5.8 ± 0.86	8.7 ± 0.93
	2	8.3	5.3 to 11.3	5.9 ± 0.85	8.8 ± 0.90
	3	2.1	0.6 to 3.3	6.6 ± 0.94	9.9 ± 0.98

6.6 ± 0.92 d °C⁻¹ (Petrie and Sadras 2008)
8 d °C⁻¹ (Tomasi et al 2011)
9.8 ± 0.94 d °C⁻¹ (Sadras and Petrie 2011).

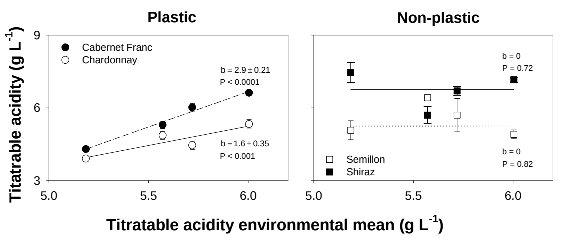
temperature effect on TA and pH is strongly dependent on variety

Vintage	Variety	TA ($g L^{-1}$) control	TA ($g L^{-1}$) heated	pH control	pH heated
2010	Semillon	6.4 ±0.12	5.1 ±0.39	3.11 ±0.0167	3.30 ±0.0780
	Chardonnay	4.9 ±0.16	3.9 ±0.12	3.52 ±0.0567	3.80 ±0.0285
	Shiraz	5.7 ±0.35	7.5 ±0.41	3.44 ±0.0458	3.40 ±0.0318
	Cab Franc	5.3 ±0.15	4.3 ±0.10	3.66 ±0.0088	3.85 ±0.0384
2011	Semillon	4.9 ±0.18	5.7 ±0.69	3.37 ±0.0318	3.54 ±0.0361
	Chardonnay	5.3 ±0.20	4.5 ±0.17	3.57 ±0.0265	3.82 ±0.0713
	Shiraz	7.2 ±0.10	6.7 ±0.18	3.37 ±0.0231	3.43 ±0.0463
	Cab Franc	6.6 ±0.06	6.0 ±0.16	3.50 ±0.0120	3.65 ±0.0208
Source of variation					
variety (V)		0.0001		0.0001	
temperature (T)		0.0185		0.0001	
season (S)		0.0011		0.3320	
V x T		0.0010		0.0008	
V x S		0.0002		0.0001	
T x S		0.7135		0.9675	
V x T x S		0.0001		0.5544	

G x E from viewpoint of phenotypic plasticity

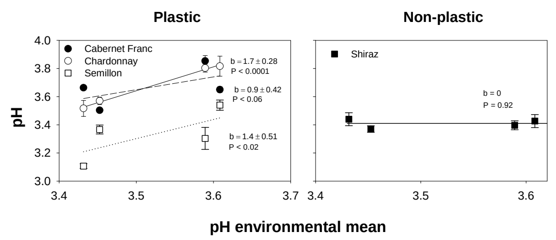


expected reduction in TA with high temperature is an oversimplification



Sadras et al. 2013 Australian Journal of Grape and Wine Research 19:107-115

text-book expected increase in pH with high temperature is an oversimplification



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variety dependent responses for TA-pH

Under our range of experimental conditions:

Response type 1 (Chardonnay, Cab. Franc)
Strong for both pH and TA

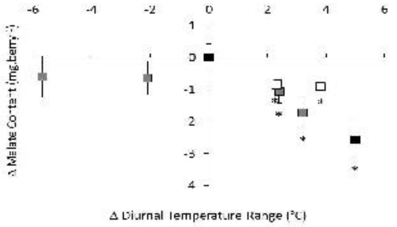
Response type 2 (Semillon)
Strong for pH, unresponsive TA (i.e. decoupled pH and TA)

Response type 3 (Shiraz)
Unresponsive pH and TA. The resilience of Shiraz is consistent with the adaptation of this variety to Barossa conditions.

Elevating maximum temperatures (4-10°C above controls) during véraison and ripening reduced malate content.

When minimum temperatures were also raised (4-6°C) malate content was not reduced.

Regulation of malate metabolism may differ during the day and night.



Sweetman et al 2014 J Exp Bot in press

Trait decoupling and wine balance

Thermal decoupling is the consequence of differential responses of related traits.

Balanced fruit

Sugars
Anthocyanins
pH
TA
Flavour compounds

temperature →

Decoupled fruit

Sugars
Anthocyanins
pH
TA
Flavour

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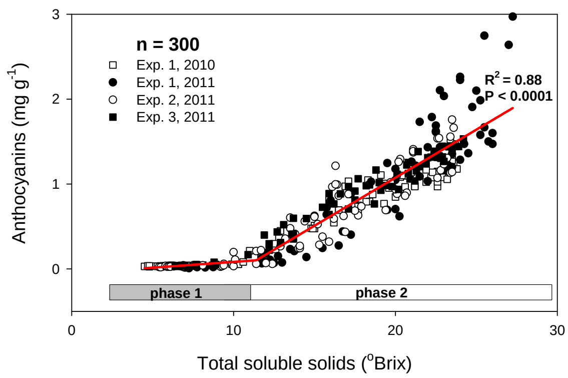
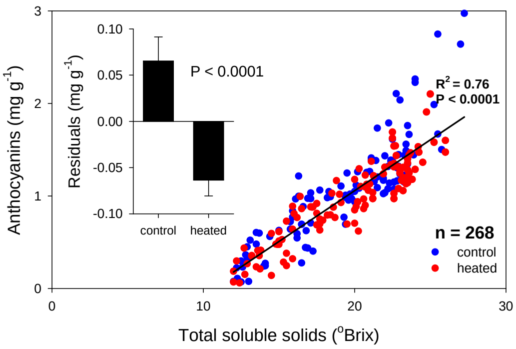
elevated temperature decouples anthocyanins and sugars



Sadras & Moran 2013 Australian Journal of Grape and Wine Research 18:115-122

Finding 6: elevated temperature decoupled anthocyanins and sugars



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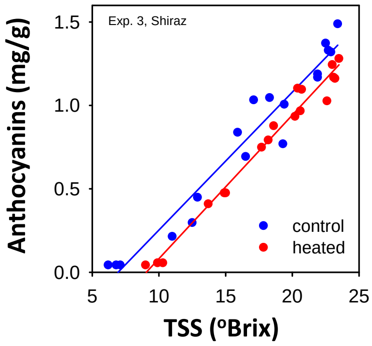
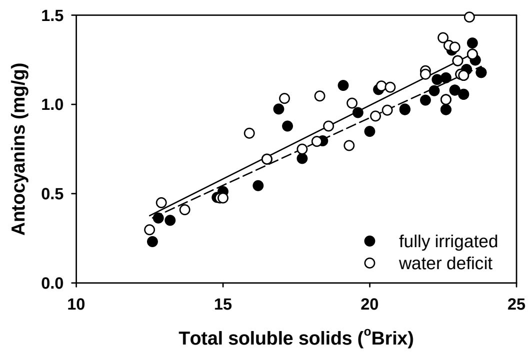
elevated temperature decoupled anthocyanins and sugars by delaying colour development in a brix scale



Sadras & Moran 2013 Australian Journal of Grape and Wine Research 18:115-122

water deficit helps restoring the anthocyanin : sugar balance



evaporative cooling is critical for tolerance to high temperature

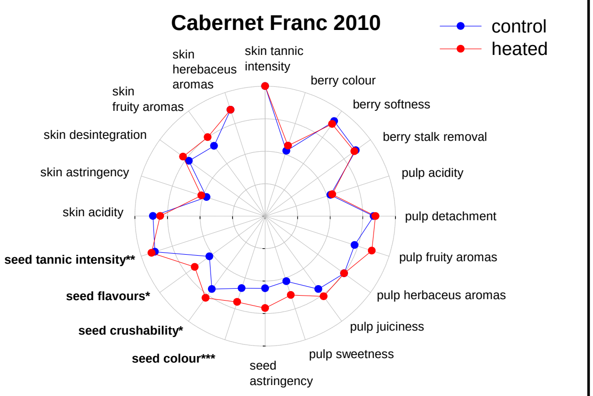
In well-watered Shiraz, short spells of heat stress (> 40 °C) or continuous elevated temperature (+2 to 4 °C) increases canopy temperature by only 1 °C or less.

Adaptations: larger more open stomata (Shiraz), higher density of wider xylem vessels (Malbec)

Tradeoff: berry balance/heat stress

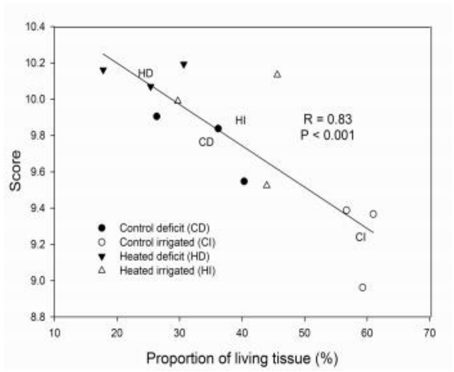
Functional Plant Biology, 36:801-814; *European J Agronomy*, 31:250-58; GiEsco 2013

temperature decoupled sensory berry traits

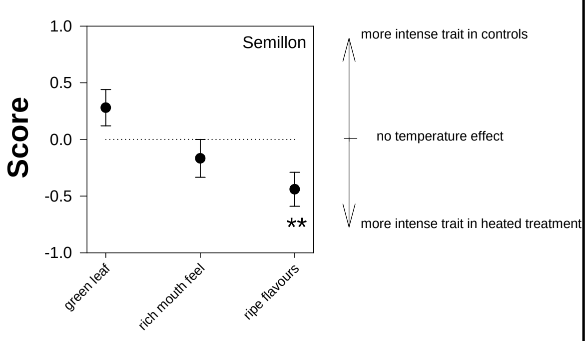


Sadras et al 2013 Australian Journal of Grape and Wine Research 19:95-106

Higher berry sensory score (20 traits, 9 panellists) with higher cell death

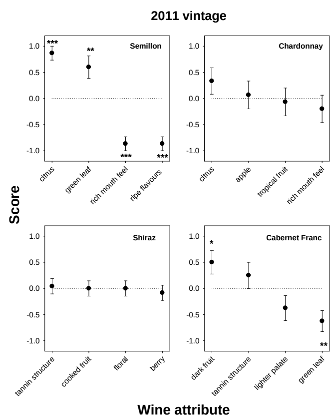


Bonada et al 2013 Irrigation Science 31:1317–1331



Sadras et al 2013 Australian Journal of Grape and Wine Research 19:107-115

strong variety x season x temperature effect on wine sensory traits



Industry implications

In intermediate (Barossa-type region), elevated temperature is neutral for yield, and shifts maturity

Strong decoupling of anthocyanins and sugars under elevated temperature

The onset of colouring is shifted to higher sugar concentration

Water deficit may partially restore balance (but increase heat damage)

Decoupling of sensory traits in berries and wines

Balance can be restored with vineyard (e.g. late pruning) and wine making interventions (e.g. differential berry crushing intensity, adjustment in maceration time and conditions)

Preserving wine identity and decompressing harvest
Wine tasting workshop: November 2014 @ Wolf Blass

Shiraz @ January 2012

Pruning date: 26 May | 27 September | 18 October

Thank you.

Australian Government
Australian Grape and Wine Authority

The FAO Penman-Monteith Shiraz

This wonderful wine has been produced exclusively with grapes harvested from vineyards irrigated using a unique combination of FAO crop coefficients and Penman-Monteith model to estimate reference evapotranspiration. Enjoy.

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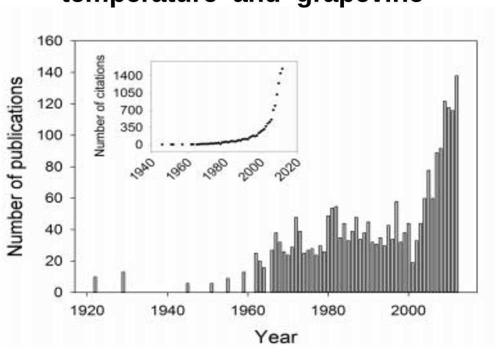
publications retrieved from Web of Science with key words
'temperature' and 'grapevine'



Bonada and Sadras 2014 Australian J Grape & Wine Research